Differentiation of ovarian carcinomas from borderline ovarian tumors by ADC histograms of the solid component.

Poster No.: C-0928
Congress: ECR 2014
Type: Scientific Exhibit
Keywords: Cancer, Imaging sequences, MR-Diffusion/Perfusion, Pelvis
DOI: 10.1594/ecr2014/C-0928

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Aims and objectives

Borderline ovarian tumors represent 15-20% of epithelial ovarian neoplasms with an incidence of 5.3 out of 100,000 women per year [1]. Because they affect young women of childbearing age, it is important to spare the fertility during the treatment. The usual surgical approach for the management of borderline ovarian tumors includes total abdominal hysterectomy, bilateral salpinogo-oophorectomy, and omentectomy, which is similar to that for malignant ovarian tumors. However, fertility-sparing surgery can be considered when pathological diagnosis is borderline ovarian tumor and FIGO stage is stage Ia (limited to one ovary with no capsule breach), because excellent prognosis has been achieved. Therefore, preoperative, imaging diagnosis for borderline ovarian tumors is important. The radiologic and morphological features which allow confident differentiation of borderline ovarian tumors from carcinomas have not been widely reported [2, 3]. It has been reported that apparent diffusion coefficient (ADC) values in the pelvic malignant tumors are statistically lower than that of the benign tumors, due to their high cellularity [4]; however, to our knowledge, difference in ADC values between borderline ovarian tumors and carcinomas has not been reported. This study aimed to examine if ADC values in the solid component can be used to distinguish between the borderline ovarian tumors and ovarian carcinoma.
Methods and materials

#Subjects# We retrospectively reviewed the MR images of the patients with ovarian tumors who underwent preoperative MRI of the pelvis from April 2008 to May 2013. The inclusion criteria were histologically proven borderline ovarian tumor and ovarian carcinoma (stage I to III). The exclusion criteria were coexistence of other ovarian tumors, obvious artifacts, and inadequate number of sequences necessary for image processing. Among 48 ovarian tumors (20 borderline tumors and 28 carcinomas) screened at first, 11 tumors were excluded (1 carcinoma for coexistence of other ovarian tumor type, 2 borderline tumors and 1 carcinoma for distortion artifacts, 2 borderline tumors and 5 carcinomas for inadequacy of sequences). Finally, 16 borderline ovarian tumors and 21 carcinomas were enrolled in this study. The age of the patients ranged from 19 to 84 years (mean age ± standard deviation = 45.6 ±19.1 years) and from 27 to 74 years (53.8 ±10.7 years), in the borderline tumor group and ovarian carcinoma group, respectively. The other clinical and histological characteristics are shown in Table1.

#MRI scan# A 1.5-T system and a standard pelvic coil was used. Axial fast spin-echo T1 weighted imaging (T1WI) (TR/TE of 620/10ms, flip angle of 90°, FOV of 250×250mm, matrix size of 288×229, echo train length of 3, and section thickness of 4mm), axial fast spin-echo T2 weighted imaging (T2WI) (TR/TE of 4000/100ms, flip angle of 90°, FOV of 250×250mm, matrix size of 320×239, echo train length of 19, and section thickness of 4mm), axial pre- and post-contrast enhanced T1WI with fat-saturation (TR/TE of 640/10ms, flip angle of 90°, FOV of 250×250mm, matrix size of 256×176mm, and section thickness of 4mm), and axial diffusion-weighted imaging (DWI) (b-factor of 1500mm²/s, TR/TE of 3057/76ms, flip angle of 90°, FOV of 360×360mm, matrix size of 288×229mm, and section thickness of 4mm) were acquired. Axial echo-planar images (EPI) with no diffusion weighting (b-factor of 0 mm²/s) were also obtained, and ADC maps were constructed from this EPI and DWI images.

#Image analysis# The flow diagram of steps and key images are shown in Figure 1,2. Co-registration of images, semi-automatic detection of tumor, extraction of the solid component of the tumor, and histogram analysis were conducted in this order. First, DWI and ADC maps were co-registered to the EPI images with no diffusion weighting, to correct for eddy current distortion and the patient's movement during acquisitions (FDT and SPM8). Next, the EPI images and all the other images were co-registered to the corresponding fast spin-echo T2-weighted images, using an algorithm based on mutual information (SPM8). This transformation information was then applied to the ADC maps. Fat and soft tissues surrounding the tumors were identified automatically based on their intensity thresholds, and removed (MRICron). The residual soft tissues, if any, were then removed manually. For these purposes, the imaging sequences which provided the greatest contrast for each tissue (e.g., T1-weighted images for fat) were used. The areas of these tissues were used as exclusion masks onto the other co-
registered images - so as to extract only tumors. The solid components of the tumors were then identified by subtracting the non-contrast-enhanced T1-weighted images from the co-registered contrast-enhanced images (ImageJ). The area of the solid component was then superimposed onto the ADC maps, and the ADC histograms were obtained for each solid tumor component (ImageJ). The bin width was set as $1 \times 10^{-3}$ mm$^2$/s.

#Statistical analysis# The normalized peak height, peak location, and the minimum of the histograms were compared between the two tumor types. Mann-Whitney U-tests were used to determine statistical significance at $p < 0.05$. 
Table 1: Lesion characteristics

<table>
<thead>
<tr>
<th></th>
<th>Borderline tumor (16 lesions)</th>
<th>Carcinoma (21 lesions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y.o)</td>
<td>53.8±10.7</td>
<td>45.6±19.1</td>
</tr>
<tr>
<td>Menopausal state</td>
<td>8/7</td>
<td>4/13</td>
</tr>
<tr>
<td>(pre/post)</td>
<td></td>
<td></td>
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<tr>
<td>Stage</td>
<td>I a: 11, I b: 2, I c: 3</td>
<td>I a: 5, I c: 7, II c: 2, III c: 7</td>
</tr>
<tr>
<td>Histology</td>
<td>Mucinous borderline 9</td>
<td>Clear cell ca 4</td>
</tr>
<tr>
<td></td>
<td>Serous borderline 6</td>
<td>Serous adeno ca 13</td>
</tr>
<tr>
<td></td>
<td>Juvenile granulosa cell tumor 1</td>
<td>Mucinous adeno ca 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Endometrioid adeno ca 3</td>
</tr>
</tbody>
</table>

Table 1

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Fig. 1

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Fig. 2: A: Identification of fat on T1WI (blue region). B: Identification of soft tissue on DWI (b=0) (blue region). C: Tumor-only images. D: Subtraction of non-contrast-enhanced T1WI from contrast-enhanced T1WI. E,F: Application of solid tumor component as inclusion mask on ADC maps.

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Results

The normalized and averaged ADC histograms of each tumor type are shown in Figure 3. The peak location of borderline ovarian tumors was significantly higher than that of ovarian carcinoma (1.60 ± 0.34 vs. 1.23 ± 0.52×10^{-3} \text{mm}^2/\text{s}, p = 0.0094) (Figure 4). The minimum ADC value of borderline ovarian tumors was significantly higher than that of ovarian carcinoma (0.85 ± 0.40 vs. 0.58 ± 0.21×10^{-3} \text{mm}^2/\text{s}, p = 0.0106) (Figure 5). There was no significant difference in the normalized peak height between the two tumor types (0.20 ± 0.10 vs. 0.17 ± 0.10, p = 0.3577) (Figure 6). Representative cases of borderline ovarian tumor and carcinoma are shown in Figure 7 and 8, respectively.
Figure 3: Normalized and averaged ADC histograms of each tumor type

Fig. 3

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Fig. 4

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Fig. 5

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Fig. 6

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Fig. 7: A 65-year-old woman. Heterogeneous intensity mass with nodular solid components (arrow). Histogram#The peak location of solid component is higher than that of ovarian carcinoma.

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**Figure 8:** ADC histogram of solid component in carcinoma

Fig. 8: A 55-year-old woman. Heterogeneous intensity mass with large nodular solid components (arrow). Histogram#The peak location of solid component is lower than that of borderline tumor.

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Conclusion

Morphological MRI features specific to borderline tumors have not been widely reported [2]. One study has reported that the thickness of septations and the size of solid components were significantly larger in carcinomas; however, neither feature allowed confident differentiation of the two tumor types [3]. ADC values of the pelvic malignant tumors are typically lower than that of the benign tumors because of their high cellularity [4]. Therefore difference in ADC values between borderline ovarian tumors and carcinomas in the present study might reflect difference in cellularity.

The results of this semiautomated analysis suggest that the peak location and minimum of the ADC histograms of the solid tumor component can be helpful in distinguishing between the borderline ovarian tumor and ovarian carcinoma.
References


